



SANDIA NATIONAL LABORATORIES

"R&D 100" Awards Entry Form

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Sandia National Laboratories

A Department of Energy National Laboratory

Revolutionary Packaging
via Removable Adhesives,
Conformal Coatings,
and Foams



Removable Adhesives, Conformal Coatings, & Foams

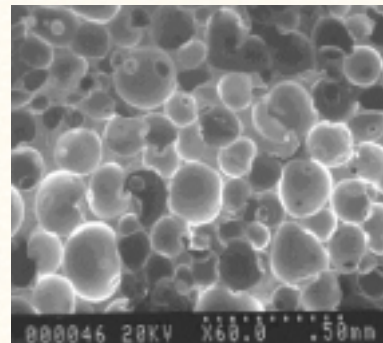
2000 R&D 100 AWARDS ENTRY FORM

1. SUBMITTING ORGANIZATION

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Submitter's Name

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Scanning electron micrograph (SEM) of a removable epoxy foam.

Affirmation

I affirm that all information submitted as a part of, or supplemental to, this entry is a fair and accurate representation of this product.

Signature

2. JOINT ENTRY WITH...

Not applicable.

3. PRODUCT NAME

Revolutionary Packaging via Removable Adhesives, Conformal Coatings & Foams

4. BRIEF DESCRIPTION OF ENTRY

(25 words or less, e.g., balance, camera, nuclear assay, etc.)

Utilizing reversible chemistries, we have developed a revolutionary packaging concept—removable thermoset materials including adhesives, conformal coatings, and foams—that allow for repairs, upgrading, and recycling assembled and encapsulated electronic components.



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Removable Adhesives, Conformal Coatings, & Foams

5. WHEN WAS THIS PRODUCT FIRST MARKETED OR AVAILABLE FOR ORDER?

Proof of actual sale or intent to sell must be submitted (i.e., invoice, marketing brochure, or a 1-page letter from a company using your product).

February 1999

Evidence & Use of Produce

This technology has been available for licensing during all of 1999. We have advertised it through a commerce business daily advertisement dated Feb. 4, 1999 (see Appendix A-2: Advertisement Copy for Removable Polyurethane Encapsulants Partnership Opportunity).

We have marketed it to U.S. industries (see Appendix A-3: Marketing Brochure on Removable Encapsulants, and see Appendix A-4: Internet Web Site).

In addition, we have initiated a cooperative research and development agreement (CRADA) with Rockwell/Collins in August 1999 (see Appendix A-5: Sandia Labs and Rockwell/Collins CRADA). This CRADA will develop a conformal coating that can be removed and allow expensive printed wiring boards to be reworked for repair or for upgrades. A letter from Rockwell/Collins is attached (see Appendix A-6) which describes their perspective on this technology.

6. INVENTOR OR PRINCIPAL DEVELOPER

Additional developers listed on a separate sheet (see Appendix A-1: List of Co-Developers/Co-Inventors).

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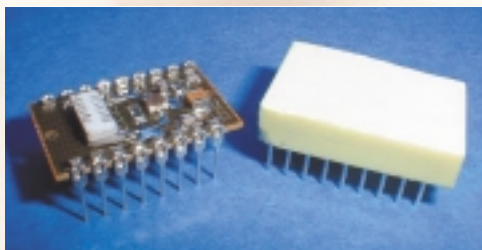
7. PRODUCT PRICE (IS THE PRICE PROPRIETARY, YES, OR NO?)

Because this technology was created at a Sandia National Laboratories (one of the U.S. Department of Energy's national labs), it is available to the private sector for licensing by Sandia Corporation.





Removable Adhesives, Conformal Coatings, & Foams



Printed wiring board (PWB) encapsulated with a removable syntactic epoxy foam.

8. PATENTS HELD

(Yes, or No?) (Attach your responses to questions 9–12 on separate pages.)

Yes. We have three patents pending for thermally removable:

- Polymeric encapsulants—which describes a general concept to prepare removable polymers based upon the Diels-Alder reversible chemistry,
- Polyurethanes—which describes a method to incorporate the reversible Diels-Alder chemistry into polyurethanes, and
- Epoxies—which describes a method to incorporate the reversible Diels-Alder chemistry into epoxies.

(See Appendix A-7: U.S. Patent Pending on the Method of Making Thermally Removable Polymeric Encapsulants, A-8: U.S. Patent Pending on the Method of Making Thermally Removable Polyurethanes, and A-9 U.S. Patent Pending on the Method of Making Thermally Removable Epoxies),

In addition, we expect to seek further patent applications this year.

Patents by Others on This or Similar Products (Yes, or No?)

No, we know of no other patents on these products. Existing patents with the closest overlap concern the use of Diels-Alder chemistry to provide thermally reversible polymer crosslinks (e.g., U.S. patent 5,726,391, "Thermosetting Encapsulants for Electronics Packaging," by Shridhar R. Iyer and P. K. Wong).

An important difference in our patents is our use of low-molecular-weight monomers (rather than polymers) that are joined (polymerized) with Diels-Alder bonds that allow many of the properties of interest (removability rather than softening of an encapsulant or an adhesive). An additional very important difference is our incorporation of the Diels-Alder chemistry into epoxy or polyurethane resins, which allow us to utilize the large range of commercial curatives—versatility in formulation directly resulting in our numerous products.





Removable Adhesives, Conformal Coatings, & Foams

9. PRODUCT'S PRIMARY FUNCTION

Utilizing reversible chemistries, we have developed a revolutionary packaging concept: removable thermoset materials including adhesives, conformal coatings, and foams. These products allow us to assemble and encapsulate (with a conformal coating and/or foam) electronic components with polymeric materials that have excellent mechanical, thermal, and solvent-resistant properties, but allow for repair, upgrading, and recycle of the assembled components. We have developed a suite of products based upon two reversible chemistries:

- Epoxy and Polyurethane Foams that are crosslinked and retain the good properties of epoxy or polyurethane (solvent resistance, modulus), but are removable,
- Syntactic Epoxy Foams (low CTE, high modulus, solvent resistance) that are removable,
- Conformal coatings that are crosslinked and retain solvent and water resistance, but are removable, and
- Hot-melt adhesives that can be removed at a lower temperature and with less force.

Frequently, we encapsulate electronic components to provide environmental protection, such as those below.

- Printed wiring boards are encapsulated with a thin polymer-conformal coating to protect the board from debris and moisture.
- Other expensive, sophisticated electronic components are encapsulated with polymer foams that provide environmental protection against moisture and debris, and structural protection against shock and vibration.
- Electronics in weapons, missiles, or the space shuttle must have very high reliability and need such shock and vibration protection.

Typically, encapsulants rely upon well-known, inexpensive, and readily processed polyurethane and epoxy chemistries. However, such encapsulants are difficult, if not impossible, to remove because they are thermosets—rendering them insoluble in most solvents. There are numerous important reasons to remove adhesives, conformal coatings, and foams especially in the microelectronics industry (i.e., failure rates may arise in manufacturing processes, and companies may want the ability to remove an encapsulant and rework components, especially expensive ones, rather than discard components.) Also, another reason to remove encapsulants may arise upon discovering a degenerative problem after a component's deployment. If a removable encapsulant was utilized, a manufacturer could pull defective items from the field, remove encapsulants, and rework the component. This feature is especially important for long-life components—such as in expensive weapons. In this case, it would be beneficial to upgrade a component as new technology came on-line. Thus, a removable encapsulant allows components to be upgraded and retain state-of-the-art technology.

Another important advancement is that removable encapsulants offer the ability to take a component apart to retrieve and recycle parts when a component reaches the end of its life. Removable encapsulants (which allow for such recycling) are important factors in recycle strategies. Also, removable adhesives are important for all of the same reasons, but before now have been unavailable.

We have developed two different removable resins that are formulated into our current set of products:

1) This is based on a reversible Diels-Alder chemistry, which forms covalent bonds (polymerizes) at 60 °C and reverses (de-polymerizes) at 90 °C. The chemistry can be incorporated into an epoxy or polyurethane resin and reacted with conventional curatives. At 60°C, the resin and curative can be reacted to form a polymer. The reactants can be formulated to prepare adhesives, foams, sealants, etc. The polymer then can be broken apart (at 90 °C) for easy removal. A demonstration of a removable epoxy foam is shown in Appendix 10.

2) With a 125 °C-reversion temperature, our second resin is based on a reversible-nitroso chemistry. Together these new resins provide great versatility in the adhesion and encapsulation of high-value electronic components and will revolutionize our thinking of what adhesion and encapsulation mean.



Removable Adhesives, Conformal Coatings, & Foams

10A. PRODUCT'S COMPETITORS

(by manufacturer, brand name, and model number)

REMOVABLE ADHESIVES:

We know of no adhesives that are thermally removable via a reversible chemistry. Our competing hot-melt adhesives have a significant advantage in that the viscosity at removal temperature is extremely low (compared to a polymeric hot melt), and the removal temperature is lower. Adhesives are available from many different sources. Listed below are some representative companies that produce the most common adhesives, some of which are hot-melts offering the common mechanical removal mechanism. (The adhesive is heated until it softens, and then the parts are pried apart.) Some representative manufacturers of adhesives include those listed in Table 1.

TABLE 1: ADHESIVE COMPETITORS

COMPANY	PRODUCT
Dexter Corp. One Dexter Dr. Sea Brook, NH 03874-4018 Phone: (800) 254-2636 Fax: (603) 474-5545	<ul style="list-style-type: none">• Dexter Hysol: one- and two-part epoxy paste adhesive systems.• Epoxy film adhesives, hot-melt adhesives
Loctite Americas 1001 Trout Brook Crossing Rocky Hill, CT 06067-3910 Phone: (800) 562-8483	Loctite Instant Adhesives: <ul style="list-style-type: none">• Activator-cured• UV-cured• Heat-cured
Dymax Corp. 51 Greenwoods Rd. Torrington, CT 06790 Phone: (888) 217-7183 Fax: (860) 496-0608	Dymax Corp. <ul style="list-style-type: none">• Dymax Light Weld: (UV cure only)• Multi-cure: (UV + activator or heat cures)• UltraLight Weld: (UV + visible cures)• Sure Cure (UV + two-part cures)• Dare Cure: (UV + O₂ curing coatings)





Removable Adhesives, Conformal Coatings, & Foams

CONFORMAL COATINGS:

We know of no manufacturer of any conformal coating claiming to have a thermal removable mechanism. In general, removing conformal coatings is possible only with those that are sensitive to solvents, except for removal by mechanical means. (Conformal coatings, also sold by many manufacturers, include epoxy, polyurethane, acrylics, silicones, and parylene.) Some representative manufacturers of conformal coatings include those listed in the following table.

TABLE 2: CONFORMAL COATING COMPETITORS

COMPANY	PRODUCTS (Acrylic, Urethane, Silicone Conformal Coatings, UV, and Parylene)
Humiseal. Woodside, NY 11377 Phone: (718) 932-0800 or (888) 854-5693 Fax: (718) 932-4345	<ul style="list-style-type: none">• "1B" acrylic—Poor resistance to solvents• "1A" urethane—Excellent resistance to solvents• "1C" silicon—Good resistance to solvents• UV—Good to excellent solvent resistance
Conap Inc. 1405 Buffalo St. Olean, NY 14760 Phone: (800) 836-3666 Fax: (716) 372-1594	Specialty formulators of PU and acrylic conformal coatings for printed circuit board applications. <ul style="list-style-type: none">• "Conathane" series—PU conformal coating• "Conap CC-1191"—acrylic conformal coating
Poly Cast Comp. 130 South Second Street Bay Shore, NY 11706 Phone: (800) 486-3512 Fax: (516) 595-2537	<ul style="list-style-type: none">• "PT-100"—Flexible urethane conformal coating• "PT-300"—Chemically resistant urethane• "PT-1000"—Electrically conductive epoxy coating
Comco Inc. 2151 N. Lincoln St. Burbank, CA 91504-3344 Phone: (800) 796-6626 Fax: (818) 955-8365	Manufacturer of systems to selectively remove conformal coatings using the <ul style="list-style-type: none">• Microabrasive Blasting Process—a mechanical means of removal
Specialty Coating Systems 5705 West Minnesota Street Indianapolis, IN 46241 Phone: (800) 356-8260	SCS provides systems and supplies for vacuum deposited Parylene conformal coatings and automated Parylene vacuum deposition systems (i.e., parylene N, C, and D dimers and A174-silane adhesion promoter.) Parylene conformal coatings can be removed by oxygen plasma





Removable Adhesives, Conformal Coatings, & Foams

FOAMS:

We know of no manufacturer of any foam that claims a removable foam. Both epoxy and polyurethane foam kits for foam encapsulation are produced and sold by a number of manufacturers. Contained in the table below are some representative manufacturers of foam kits.

TABLE 3: FOAM COMPETITORS

10B. PRODUCTS AND COMPETITORS' KEY FEATURES MATRIX

[include both numerical (data) and descriptive (written) comparisons]

COMPANY	PRODUCTS (Epoxy and Polyurethane)
EPOXY: Applied Poleramic 850 Teal Drive Benicia, CA 94510 Phone: (707) 747-6738	<ul style="list-style-type: none">• EF-1—a three part epoxy foam. Removable by aggressive solvents or mechanical means.
POLYURETHANE: Utah Foam Products 3609 South 700 West P.O. Box 70838 Salt Lake City, UT 84119 Phone: (801) 269-0620	<ul style="list-style-type: none">• Aquathane, water-blown rigid polyurethane foam. Removable by aggressive solvents.
General Plastics Manufacturing Co. 4901 Burlington Way P.O. Box 9097-T Tacoma, WA 96409 (800) 806-6051	<ul style="list-style-type: none">• "Last-A-Foam"—rigid and flexible polyurethane foam kits. Removable by aggressive solvents.
IPI International Inc. 505 Blue Bau Road P.O. Box 70 Elkton, MD 21922-0070 Phone: (410) 392-4800	<ul style="list-style-type: none">• IsoFoam, R-1034 Series MDI-based rigid polyurethane foam kits. Removable by aggressive solvents.





Removable Adhesives, Conformal Coatings, & Foams

TABLE 4: NEW REMOVABLE FOAMS, STANDARD SANDIA FOAMS & SOME COMERCIAL FOAMS: PROPERTY COMPARISONS

Encapsulants	Sandia Epoxy Foam, EF-AR10/20	Sandia Removable Epoxy Foam, EF-AR10/20	BKC-44402 Common Sandia Polyurethane Foam	Filled Epoxy Epon 828/DEA with glass microballoons	REM-ENCAP-1 removable epoxy filled with glass microballoons
Properties					
Density Range	8 to 20 lb _m /ft ³	8 to 20 lb _m /ft ³	2 to 20 lb _m /ft ³	50 lb _m /ft ³	50 lb _m /ft ³
Modulus/Glass Transition Temperature	49000 psi for 20 lb _m /ft ³ T _g = 90°C	26000 psi for 20 lb _m /ft ³ T _g = 78°C	46000 psi for 20 lb _m /ft ³ T _g = 129 °C	49000 psi T _g = 70°C	Approx. 49000 psi T _g = 78°C
Coefficient of Thermal Expansion	61x10 ⁻⁶ / °C	61x10 ⁻⁶ / °C	70x10 ⁻⁶ /°C	35x10 ⁻⁶ /°C	39x10 ⁻⁶ /°C
Processability	Good, Low viscosity	Good, Low viscosity	Good, Low viscosity	Adequate, High viscosity	Adequate, High viscosity
Aging Stability	Excellent	Excellent	Excellent	Excellent	Excellent
Cost to Encapsulate	\$1.0 X (comparative estimate)	\$2.0 X (comparative)	\$0.9 X (comparative)	\$1.0 Y (comparative)	\$2.0 Y (comparative)
Ease of Removability	Difficult, with aggressive solvents or mechanical means	Easy, n-butanol dissolution at 90°C	Difficult, only with aggressive solvents	Difficult, with aggressive solvents or mechanical means	Easy, n-butanol dissolution at 90°C
Cost of Removability	\$1.0 Z (comparative)	\$0.1 Z (comparative)	\$2.0 Z (comparative)	\$2.0 Z (comparative)	\$0.2 Z (comparative)





Removable Adhesives, Conformal Coatings, & Foams

**TABLE 5: NEW HOT MELT & COMMERCIAL HOT-MELT ADHESIVES:
PROPERTY COMPARISONS**

Hot Melt Adhesive Properties	Sandia Removable Hot Melt Adhesive	Hysol QuickPac™	Hysol CoolMelt™	Hysol SuperPac™	Hysol Polyolefine (EVA) 236
Softening Point, °F	247°F (120°C)	224°F	208°F	208°F	180°F
Viscosity (Centipoise)	500 @ 256°F (125°C)	3000 @ 350°F	7200 @ 350°F	4900 @ 350°F	8500 @ 350°F
Heat Resistance	212°F (100°C)	174°F	140°F	144°F	140°F
Cost of Adhesive	\$2.0 X (comparative estimate)	\$1.0 X (comparative)	\$1.0 X (comparative)	\$1.0 X (comparative)	\$1.0 X (comparative)
Typical Applications	Metals (Al, SS), glass, some plastics, wood & paper, foams	Cardboard	Paper, Styrofoam, Plastics, Softwood	Cardboard, Foam	General Purpose





Removable Adhesives, Conformal Coatings, & Foams

10C. DESCRIPTION OF PRODUCT'S IMPROVEMENT OVER COMPETITORS

(BE SPECIFIC! Include such items as how much faster, how much less cost, etc.)

Removability concepts for encapsulants and adhesives are quite unique. Until now, the industry generally has failed to concern itself with removability features in competing adhesives, conformal coatings, and foams. However, this removability is an enabling technology, which will play an important role in the future by allowing the repair, upgrading, and eventual recycling of numerous electronic components.

Product Benefits (also state in list with bullets)

Below is a list of benefits provided by our removable adhesives, conformal coatings, and foams:

- Allows rework of production units by enabling one to take apart adhesive joints and/or remove conformal coating and foams;
- Allows for the upgrading of deployed electronic components via the sequence of removing adhesives, conformal coatings and foam, reworking the electronics, and then re-assembly; and
- Allows for environmentally conscious disassembly and recycling by enabling one to fully take apart electronic assemblies.

REMOVABLE ADHESIVES:

Our approach to adhesives is different from all of our competitors. Typically, removing adhesives is accomplished by heating the adhesive above its softening point and prying the materials apart. For example, a hot-melt adhesive consists primarily of a polymer. Above its softening point, a joint bonded with a hot-melt adhesive can be pulled apart. However, softened polymers are extremely viscous (making removal difficult), and the viscous polymer could have a sufficient modulus to deform or break delicate components during disassembly.

By comparison, our competing hot-melt adhesive is also a polymer at operating temperatures. However, because of the reversible chemistries, our hot melts at removal temperatures de-polymerize and become low-viscosity liquids. (The viscosity will be an order of magnitude lower than a competing hot-melt adhesive.) In some instances, the bonded joint simply will fall apart under the weight of the parts themselves at the elevated removal temperature. In all cases, our bonded joints can be taken apart with much less force because our adhesive has been de-polymerized to a relatively low-molecular-weight liquid. In application, our new adhesives will allow assemblies to be taken apart for defect repair, component maintenance/upgrading, and the eventual recycling of component constituents.





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CONFORMAL COATINGS:

Our approach to conformal coatings is also unique. We are developing conformal coatings that are removable due to the depolymerization of the coating at an elevated temperature. Also, since our polymers are thermally reversible, we can use the monomers to coat a substrate rather than the polymers of traditional removable conformal coatings. This allows us to use higher monomer concentrations and less carrier solvent [usually a volatile organic compound (VOC)]. Hence, we use less VOCs to apply our coatings—which offers a significant environmental advantage.

FOAMS:

Foam removability in competing technologies can be accomplished only by the use of aggressive solvents or mechanical means. An example of the first is the use of 1-methyl-2-pyrrolidone (NMP) to remove an epoxy foam. Although it is possible to remove epoxy foam by soaking it in this NMP solvent at an elevated temperature, there are greater risks both to personnel and the remaining parts with NMP or similar aggressive solvent.

Our removable foams can be extracted with 1-butanol. The benefits of 1-butanol include:

- Much-less-aggressive solvent,
- Poses fewer health risks to personnel, and
- Has no effect on printed wiring boards and other materials, which one does not want to extract along with the foam.

Our technology allows our removable foams to be removed by dissolving in 1-butanol at 90°C. This mild solvent (even at this temperature) does not effect printed wiring boards, wire insulation, etc. In fact, using an aggressive solvent renders the removal process destructive and, therefore, not useful for component repair and upgrading since too many electronic parts (i.e., boards and wire insulation) will be effected. Mechanical means of removal similarly are very limited. Bead blasting, plasma etching, and physically digging out encapsulants usually result in collateral damage to components. In addition, mechanical means of removal are slower and, therefore, much more expensive.

Although there are some water-soluble and biodegradable natural-foam products (based upon natural ingredients, such as cornstarch or sorghum grain), we do not consider these competitors for electronic encapsulation. First, these products are not foamed in place uniformly to fill a volume; they normally are extruded and chopped. Secondly, water sensitivity usually is not desired around electronic components. Finally, these products do not have the physical properties (e.g., modulus) comparable to epoxy or polyurethane foams.





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11A. PRODUCT'S PRINCIPAL APPLICATIONS

The principal applications of this product are for the assembly and encapsulation of high-value electronic components in order to protect them from environmental factors, shock and vibration, and for structural support.

REMOVABLE ADHESIVES:

Removable adhesives are used to form metal/metal joints, foam/metal joints, and foam/foam joints that subsequently can be taken apart with no collateral damage to components. Together, these products allow for repairs, upgrades, and eventual dismantlement of assemblies.

For foam-to-foam adhesive bonds, we have prepared a hot-melt adhesive viscous enough such that the adhesive does not significantly flow into the foam, but allows the bond to be broken apart at 90°C.

- The effectiveness of this adhesive is manifested by the fact that the bond comes apart (and not the foam) at removal temperatures since the foam (by nature) has a very low modulus.

Competing hot-melt adhesives would not be effective for this application because the modulus of competing polymeric hot melts is much higher than our removable hot melts.

For metal-to-metal bonds, we have utilized a low-viscosity, removable hot melt, which allows for easy joint breaking at 90°C.

- The bond can be taken apart often only by the weight of the adhered parts and no additional force. Competing hot-melt adhesives would require a much more significant removal force because of the higher modulus of the polymeric hot melt which often leads to collateral damage.

ENCAPSULANTS (Conformal Coatings and Foams):

With advances in technology, especially in microelectronics, it has become important and cost-effective to remove encapsulants to repair or replace components in a multi-component system.

The principal forms for our removable encapsulants include:

- Removable conformal coatings,
- Blown foams, and
- Syntactic foams.



As a conformal coating, they can be used to protect printed circuit boards where there is a need to keep moisture and debris away from the circuitry. Some printed wire boards are





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relatively cheap, except for a few components on the board, which are orders of magnitude more expensive than the board itself. If the board fails after final assembly, it is difficult to remove the expensive components if they are conformally coated.

With our removable conformal coating, the coating can be removed for easy recovery of the expensive components. As blown and syntactic foams, they can be used as a lightweight (low-modulus) protection that later can be removed for component repair, upgrading, or recycle. Some printed wire boards are first conformally coated, and then when the assembly is complete, the entire assembly is encapsulated with foam. Using our removable products, the board can be assessed after removal of the foam. Components on the board then can be accessed by removal of the conformal coating. This allows for rapid single-component replacement (eliminating either total assembly replacement or even total board replacement).

- Designed as two-component curing systems to be processed with the same ease as traditional polyurethane and epoxy-curing systems, our removable encapsulants are easily removed by mild thermal treatment. Although not limited to epoxy- or polyurethane-based applications, their versatility allows them to be incorporated into these traditional systems.

11B. THE PRODUCT'S OTHER POSSIBLE CURRENT APPLICATIONS

Our new removable adhesives, conformal coatings, and foams create new thermoplastics from traditional thermosets that provide more versatile processing. We expect these products to be used in a very wide range of new applications. Some of these include:

- Repairable or removable paint,
- Adhesives for numerous low-temperature applications (e.g., wallpaper adhesives),
- Recyclable foam (e.g., recyclable polyurethane foams), and
- Removable underfill for flip-chip assemblies.

They also can dramatically reduce costs by allowing for single-component replacements rather than total-system replacements in multi-component systems.

11C. POTENTIAL APPLICATIONS AND WHY NOT CURRENTLY FEASIBLE FOR PRODUCT

We hope to eventually develop a suite of resins that can be formulated into products and can be removed under different environmental stimuli. Currently we have successfully developed two different resins 1) one reverses at 90°C, and 2) the other at 125°C.

If we develop resins that are removable at higher temperatures or with different stimuli (other than heat), then we can address new higher-temperature applications. Such applications might include automotive and other high-temperature electronic needs.





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12. SUMMARY OF PRODUCT'S IMPORTANCE AND BENEFITS (in layman's terms why you feel your product should receive an R&D 100 Award. Why it's important to have this product? What benefits will it provide?)

Our new products (removable adhesives, conformal coatings, and foams) rely on old and valuable ideas that previously have been unrealizable. Our concept of using a reversible chemistry to obtain removability of thermoset materials offers a revolution in packaging. The oxymoron of our concept is that we have developed thermoplastic thermosets.

Equally important is our approach in developing resins containing the reversible chemistry into well-known and accepted chemistries—namely epoxies and polyurethanes. This approach enables us to develop a wide range of new products, and many more are possible.

Removable packaging will be an important component of a greener society, when products are developed with their eventual recycle in mind. The economic advantage of such packaging will be equally important. No longer will defective products (detected only at the end of assembly) be simply tossed away. Instead, they will be dismantled and defective parts replaced. For high-value products, we will be able to un-package and refurbish products. Hence, the impact of our new products will come full circle—from being manufactured and to having the product's life extended before final dismantlement.

In the event that this technology wins an "R&D 100 Award," this accomplishment would help promote and highlight the use of these new products and lead to their rapid incorporation into numerous products.

The Wow! Factor

Encapsulants have been used to protect delicate and expensive electronic components for the past 30 years—relying heavily on epoxy and polyurethane chemistries because of the excellent properties of these thermosets. Similarly, polymeric adhesives have been used to assemble the same for much longer.

However, *our new product set makes a quantum leap* in the versatility of these polymeric products—removability.

Removability in our packaging strategies is an idea ripe for the new century because it is both cost effective to do so and environmentally sound. No longer will we throw away products with defects discovered only at the end of assembly, nor will we necessarily throw away assemblies when their technology fails to be "state-of-the-art." Removable packaging will give us a whole new set of options to repair, upgrade, and recycle!





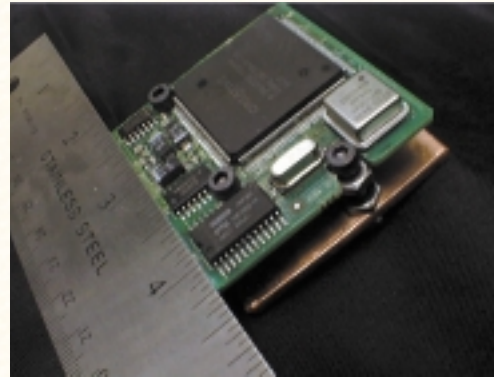
Removable Adhesives, Conformal Coatings, & Foams

ORGANIZATION DATA

13. ORGANIZATION LEADER

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A pristine PWB recovered after removal of an epoxy form.

14. CONTACT PERSON FOR ARRANGEMENTS (on exhibits, banquet, and publicity)

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APPENDIX

